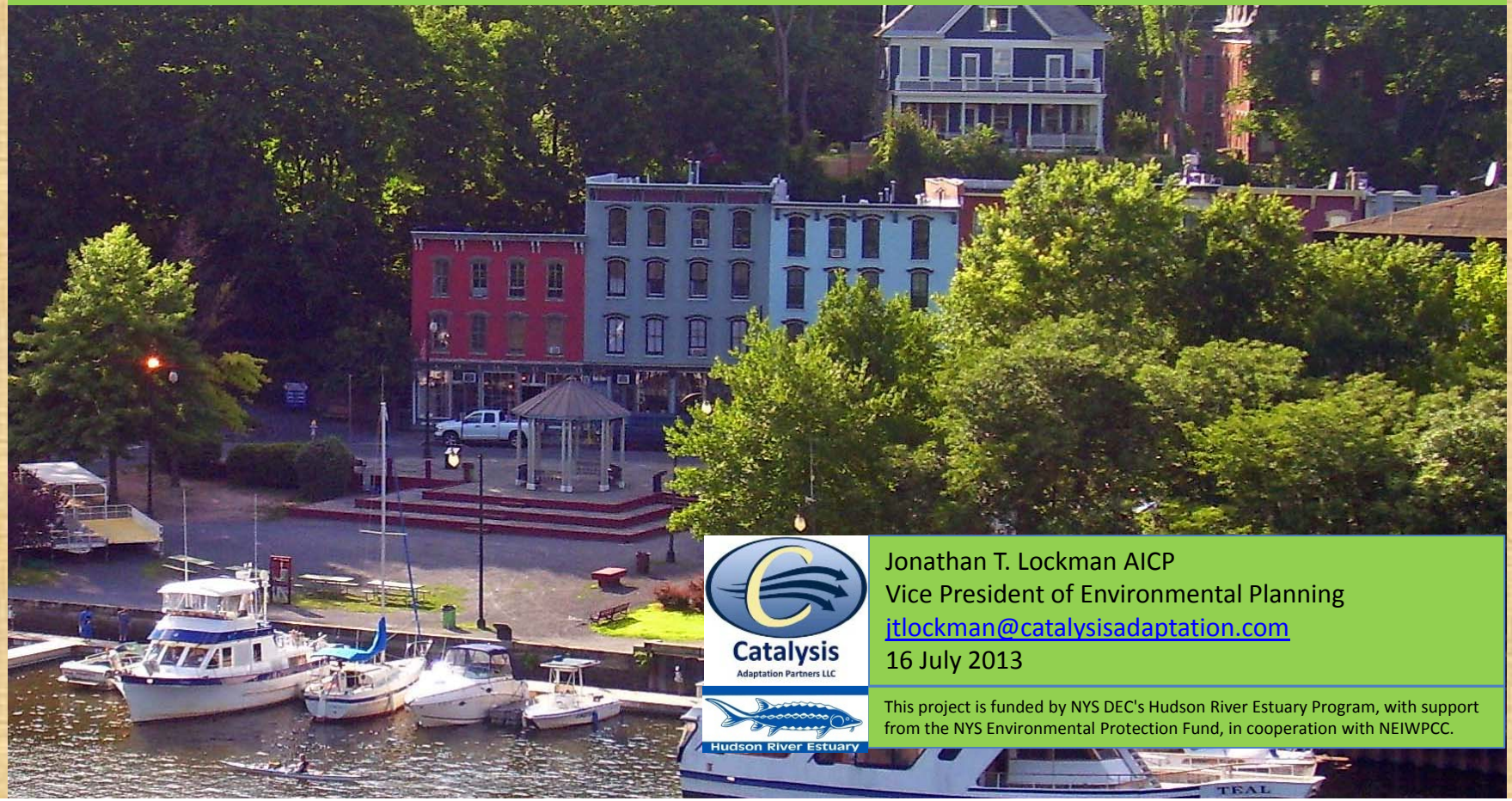
Flooding Vulnerability Assessment for the City of Kingston, NY
Benefit Cost Analysis of Three Adaptation Options for the Rondout/East Strand

- *For 10-year and 100- year Storm Events*
- *With High and Low Sea Level Rise Scenarios*
- *For the Years 2013, 2060 and 2100*
- *Including Predictions for All Cumulative Expected Monetary Damage to Buildings and Improvements using the COAST tool, and Predictions for Avoided Damages with Adaptations*



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What is “COAST?”

COastal

Adaptation to

Sea level rise

Tool

Helping Communities Decide on Sea Level and Storm Surge Adaptation Strategies with the COAST software tool

- COAST is flexible; it can provide cost-benefit analysis for many candidate adaptation actions to protect a diversity of vulnerable assets, staged over time.
- Different scenarios for sea level rise and storm surge can be inputted in to the model, after stakeholder engagement. Stakeholder engagement delivers buy-in.
- Vulnerabilities to damage are mapped and quantified based on the scenarios.
- Costs of adaptation strategies are estimated, using expert opinion. The software will generate prediction of cumulative expected damages avoided over time, with different strategies providing a cost benefit analysis.

There are only four options:

1) Do nothing (usually = remain in denial)
2) Accommodate higher water levels
3) Fortify assets
4) Relocate assets

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COAST is a tool and approach to help evaluate costs and benefits of these options. Step 1 is a vulnerability assessment, to help decide which of these options to pursue.

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Some Important Acronyms
You Need to Know for Discussing this Topic:

SLR = **S**ea **L**evel **R**ise

MHHW = **M**ean **H**igher **H**igh **W**ater**:** The average of the elevations of the highest tide each day over a specific 19-year period (a tidal "epoch." For Kingston the current MHHW is 3.0 feet (NAVD 88).

NAVD 88 = The **N**orth **A**merican **V**ertical **D**atum of 19**88** (NAVD88) is the vertical system of measurement established for vertical control surveying in the US. It sets the zero point against which all elevations are compared. (Hint: Zero is not at the current high tide level, and that's why the current MHHW in Kingston is 3.0 feet NAVD 88.)

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COAST Model for City of Kingston
Modeled Water Levels and Vulnerability Assessment Results

Year	Sea Level Rise Scenario	Storm Intensity (return period in years)	Predicted Elevation of Flood Height from FEMA Flood Insurance Study, 2007 NAVD88 (ft.)[1]	COAST Model of Sea Level Rise Above MHHW in 2013 Selected by Kingston (in./ft)[2]		COAST Model Total Flood Elevation for Each Scenario NAVD 88 (ft.)	COAST Model Expected Damage to the Value of All Buildings & Improvements From This Single Storm Incident in the Scenario Year ($ Million)	COAST Model Cumulative Expected Value of All Buildings and Improvements Located on Properties Permanently Inundated by Sea Level Rise if No Action is Taken, by this Year ($ Million)[4]	COAST Model Cumulative Expected Damage to the Value of All Buildings & Improvements From Sea Level Rise and All Storms, 2013 to Scenario Year ($ Million)	COAST Model Cumulative Expected Damage to the Value of All Buildings & Improvements From Sea Level Rise and All Storms, 2013 to Scenario Year ($ Million, with Discounting)[3]
2013	1-No SLR	10 yr	6.0	0	0	6.0	1.0	n/a	n/a	n/a
2013	2-No SLR	100 yr	8.2	0	0	8.2	18.9	n/a	n/a	n/a
2060	3-Lo SLR	10 yr	6.0	20	1.67	7.7	17.3	2.0	85.1	42.5
2060	4-Lo SLR	100 yr	8.2	20	1.67	9.9	23.7	2.0	85.1	42.5
2060	5-Hi SLR	10 yr	6.0	36	3	9.0	20.0	2.0	94.2	48.9
2060	6-Hi SLR	100 yr	8.2	36	3	11.2	26.2	2.0	94.2	48.9
2100	7-Lo SLR	10 yr	6.0	33	2.75	8.8	19.9	2.0	171.6	52.7
2100	8-Lo SLR	100 yr	8.2	33	2.75	11.0	26.0	2.0	171.6	52.7
2100	9-Hi SLR	10 yr	6.0	68	5.67	11.7	1.9	55.3	126.7	50.6
2100	10-Hi SLR	100 yr	8.2	68	5.67	13.9	3.2	55.3	126.7	50.6

[1]Tidal state is included in FEMA FIS predicted flood elevations for the 10-yr and 100-yr storms.
[2]Elevation of Mean Higher High Water (MHHW) in year 2013 is 3.0 feet (NAVD 88).
[3]Discount Rate of 3.3 percent applied.
[4]See spreadsheet for complete list of properties.

Dates Run: 06/25-30/2013

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Key Points from the Vulnerability Assessment

- The Wastewater Treatment Plant arises as the most expensive improved land needing protection.
- The model is over-predicting the expected dollar damage to the plant, as such a facility is more resilient to flooding than a normal commercial building. Further modeling of the expected damage to the wastewater treatment plant should be undertaken with a specialized depth-damage function.
- Flooding from the Esopus Creek and other localized stormwater flows were not included in the analysis. Only tidally-influenced Rondout Creek and Hudson River water level flooding was modeled.

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Key Points from the Vulnerability Assessment

- Stillwater flooding was modeled (like rising water in a bathtub). Wind, wave or erosion effects were not included.
- The Ulster County/City of Kingston Tax Assessment data from 2012 were used to assign values to the improvements to land at each parcel location.
- LiDAR data funded by NYSDEC and processed by Scenic Hudson was used to compute the land elevation.
- A Depth-Damage Function from the U.S. Army Corps of Engineers was utilized, to estimate the dollar damage to each building from each foot of flood water. (Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies, IWR Report 96-R-12, May 1996, Figure V-2)

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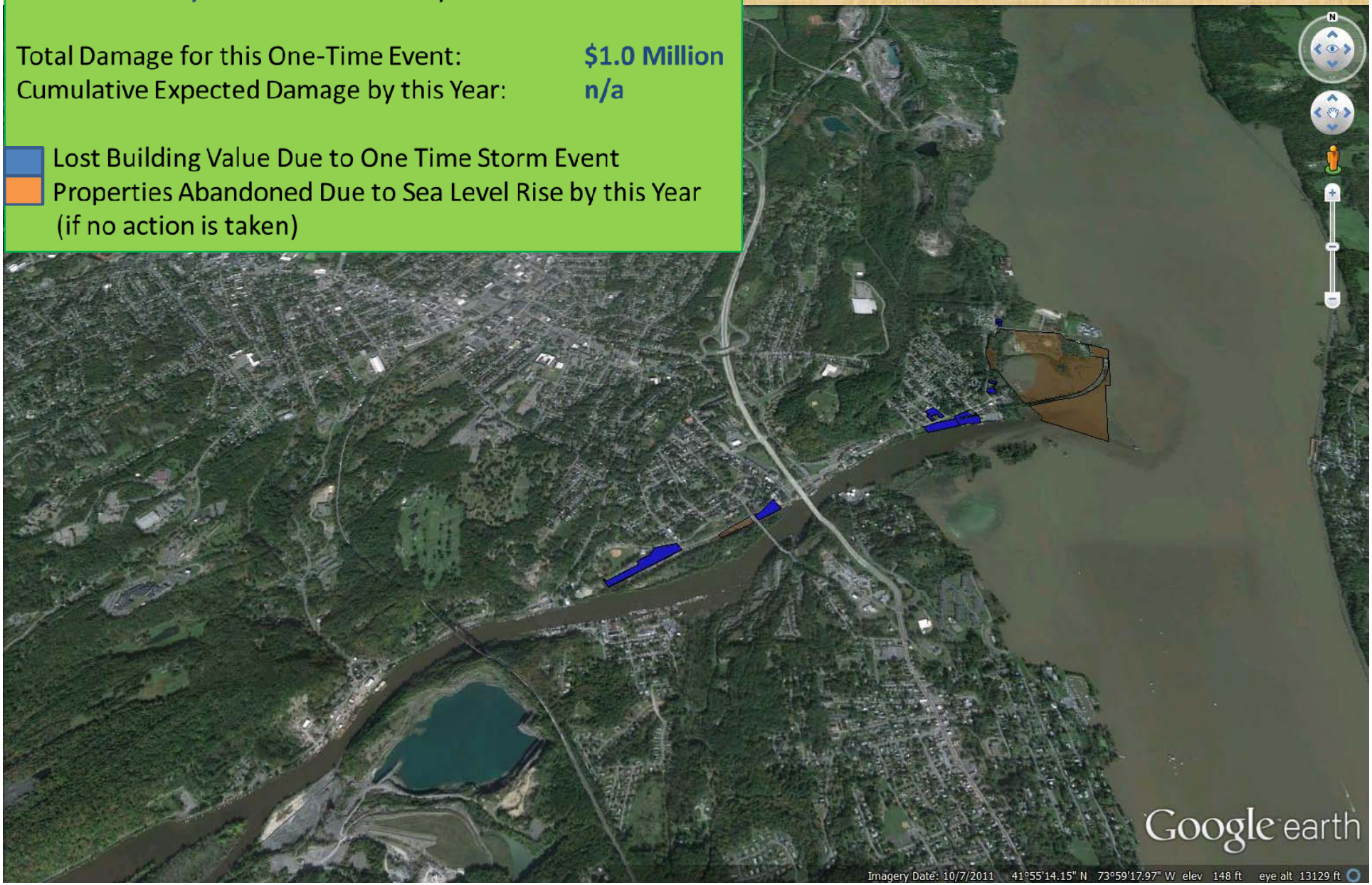
- A dozen parcels are predicted to be inundated by 2030, in either the Low or High Sea Level Rise Scenario.
- In the High Sea Level Rise Scenario, the model predicts an additional 39 properties to be inundated by 2070, including the Wastewater Treatment Plant, if no action is taken.
- The model indicates that sea level rise will inundate parcels in groupings during certain decades, rather than gradually over time. (See gaps in chart below.)

Parcels inundated by Sea Level Rise if no action is taken – Kingston Waterfront				
By the Year	Low Sea Level Rise Scenario		High Sea Level Rise Scenario	
	Number of Parcels	Value of Buildings ($ million)	Number of Parcels	Value of Buildings ($ million)
2020	3	1.3	12	2.1
2030	9	0.8		
2070			39	53.3
Totals	12	2.1	51	55.4

Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #1**, Flood Height: **6.0 ft.** (NAVD 88)
Year **2013**, With **No Sea Level Rise** and a **10-year Storm**
10% Probability of Occurrence in Any Given Year

Total Damage for this One-Time Event: **$1.0 Million**
Cumulative Expected Damage by this Year: **n/a**

Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)



Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #2**, Flood Height: **8.2 ft.** (NAVD 88)
Year **2013**, With **No Sea Level Rise** and a **100-year Storm**
1% Probability of Occurrence in Any Given Year

Total Damage for this One-Time Event: **$18.9 Million**
Cumulative Expected Damage by this Year: **n/a**

Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)

Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #3**, Flood Height: **7.7 ft.** (NAVD 88)
Year **2060**, With **Low Sea Level Rise** and a **10-year Storm**
10% Probability of Occurrence in Any Given Year

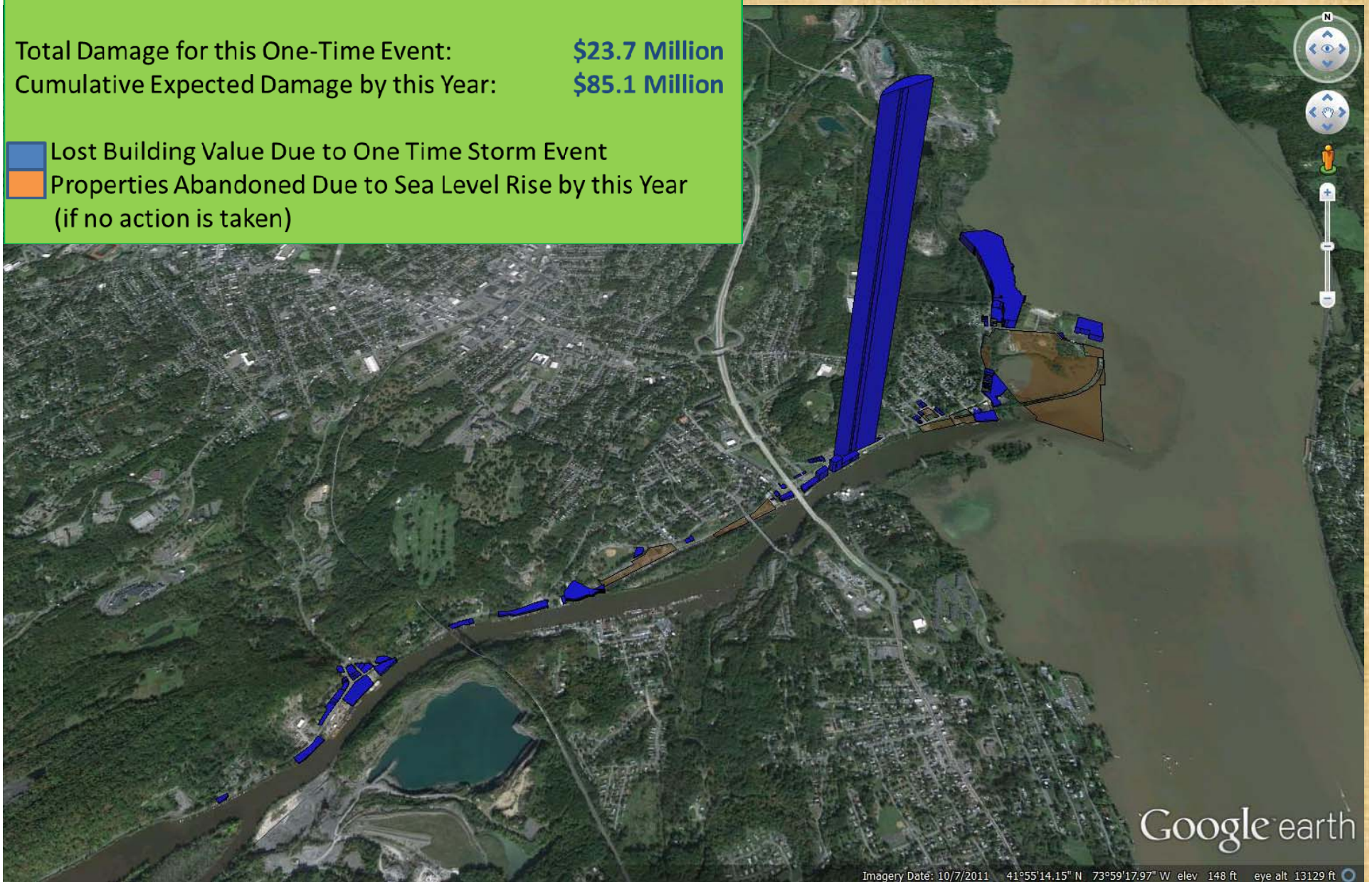
Total Damage for this One-Time Event: **$17.3 Million**
Cumulative Expected Damage by this Year: **$85.1 Million**

Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)

Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #4**, Flood Height: **9.9 ft.** (NAVD 88)
Year **2060**, With **Low Sea Level Rise** and a **100-year Storm**
1% Probability of Occurrence in Any Given Year

Total Damage for this One-Time Event: **$23.7 Million**
Cumulative Expected Damage by this Year: **$85.1 Million**

Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)



Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #5**, Flood Height: **9.0 ft.** (NAVD 88)
Year **2060**, With **High Sea Level Rise** and a **10-year Storm**
10% Probability of Occurrence in Any Given Year

Total Damage for this One-Time Event: **$20.0 Million**
Cumulative Expected Damage by this Year: **$94.2 Million**

Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)

Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #6**, Flood Height: **11.2 ft.** (NAVD 88)
Year **2060**, With **High Sea Level Rise** and a **100-year Storm**
1% Probability of Occurrence in Any Given Year

Total Damage for this One-Time Event: **$26.2 Million**
Cumulative Expected Damage by this Year: **$94.2 Million**

Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)

Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #7**, Flood Height: **8.8 ft.** (NAVD 88)
Year **2100**, With **Low Sea Level Rise** and a **10-year Storm**
10% Probability of Occurrence in Any Given Year

Total Damage for this One-Time Event: **$19.9 Million**
Cumulative Expected Damage by this Year: **$171.6 Million**

Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)

Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #8**, Flood Height: **11.0 ft.** (NAVD 88)
Year **2100**, With **Low Sea Level Rise** and a **100-year Storm**
1% Probability of Occurrence in Any Given Year

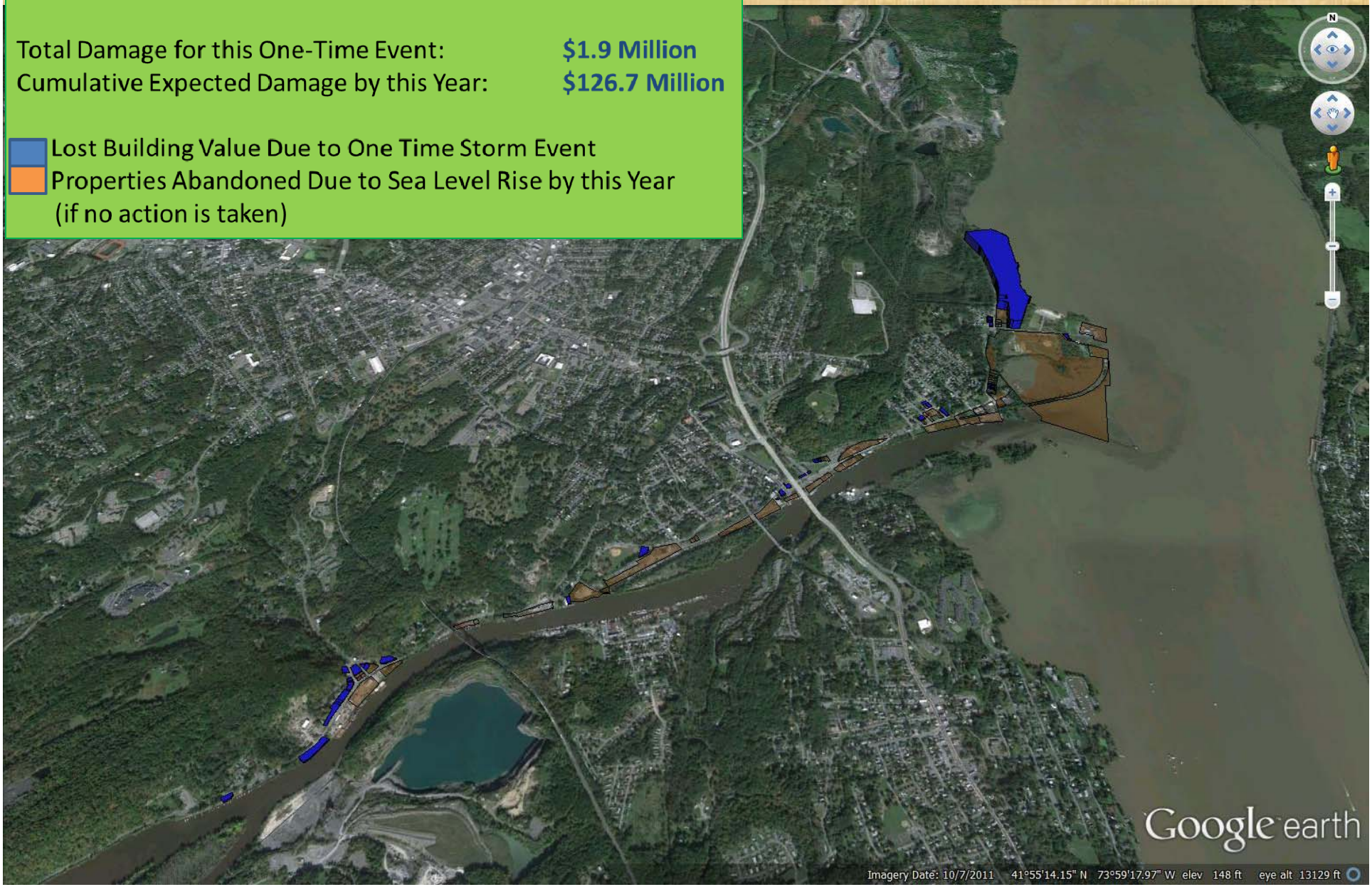
Total Damage for this One-Time Event: **$26.0 Million**
Cumulative Expected Damage by this Year: **$171.6 Million**

Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)

Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #9**, Flood Height: **11.7 ft.** (NAVD 88)
Year **2100**, With **High Sea Level Rise** and a **10-year Storm**
10% Probability of Occurrence in Any Given Year

Total Damage for this One-Time Event: **$1.9 Million**
Cumulative Expected Damage by this Year: **$126.7 Million**

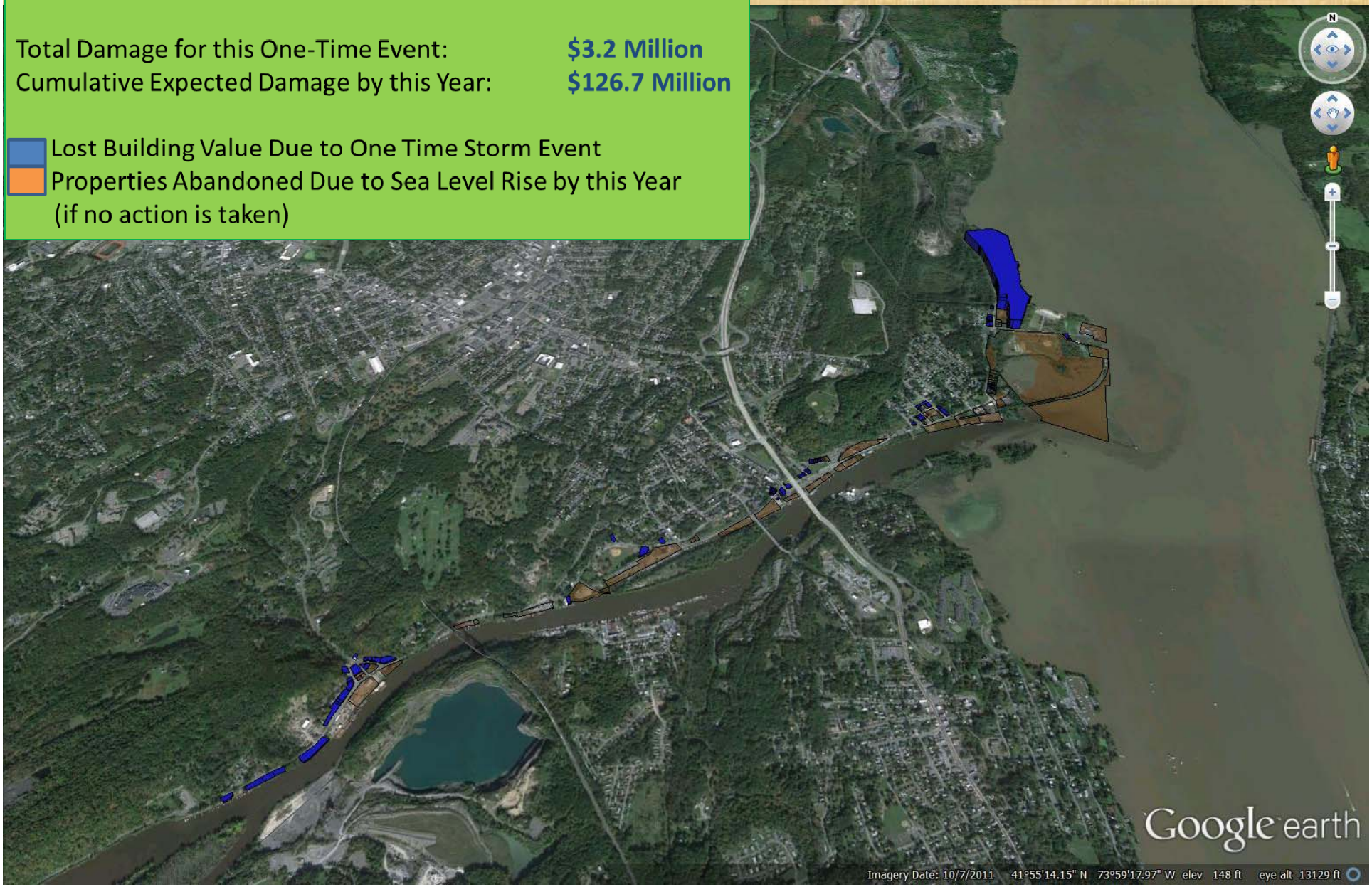
Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)



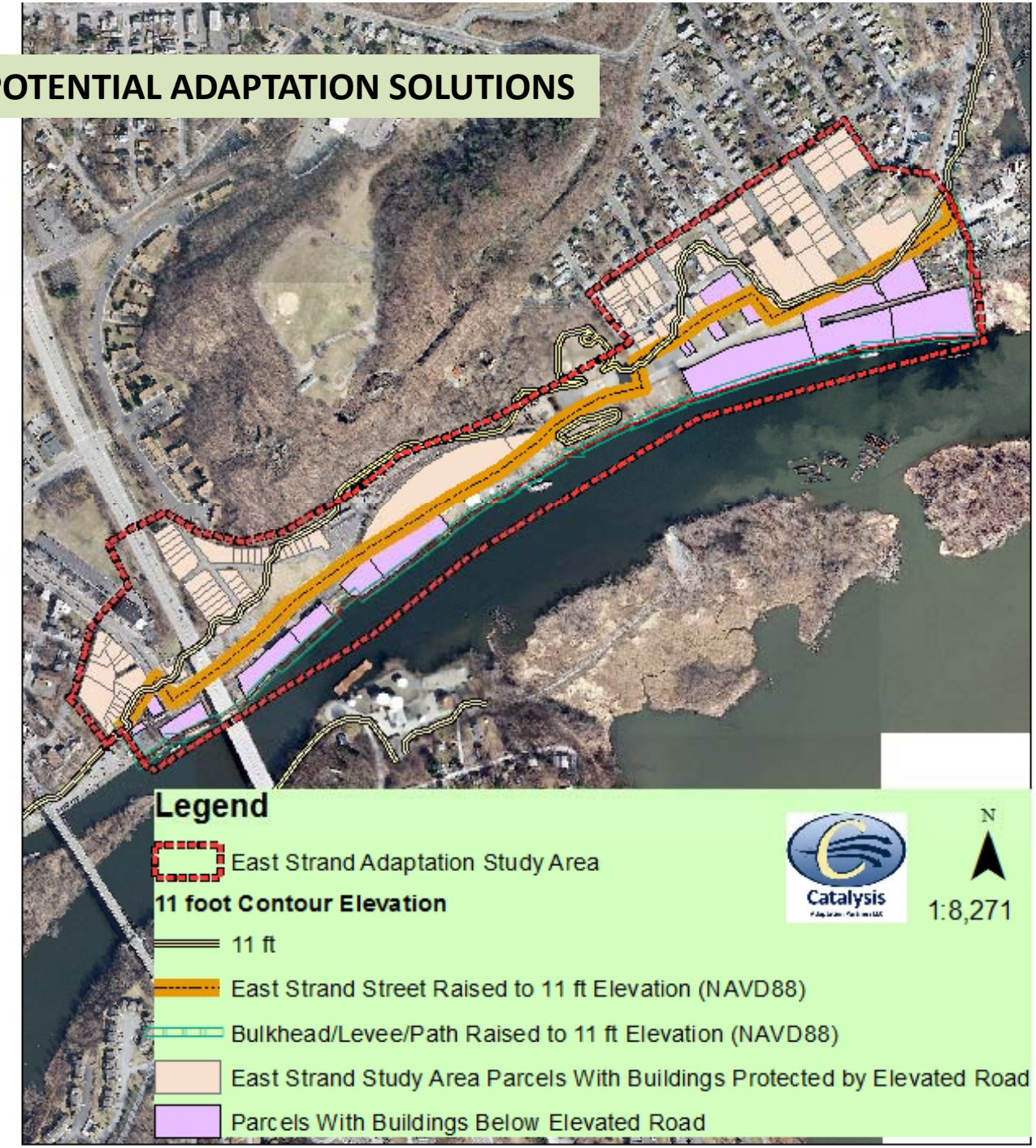
Lost Value of Buildings and/or Improvements to Land
For **Flooding Scenario #10**, Flood Height: **13.9 ft.** (NAVD 88)
Year **2100**, With **High Sea Level Rise** and a **100-year Storm**
1% Probability of Occurrence in Any Given Year

Total Damage for this One-Time Event: **$3.2 Million**
Cumulative Expected Damage by this Year: **$126.7 Million**

Lost Building Value Due to One Time Storm Event
Properties Abandoned Due to Sea Level Rise by this Year
(if no action is taken)



POTENTIAL ADAPTATION SOLUTIONS



COAST Model for City of Kingston
BENEFIT/COST ANALYSIS of Adaptation Strategies

					COAST Model Cumulative Expected Damage to the Value of All Buildings & Improvements in the EAST STRAND STUDY AREA From Sea Level Rise and All Storms, 2013 to 2100 (Dollars)[1]			
Year	Sea Level Rise Scenario	COAST Model of Sea Level Rise Above MHHW in 2013 of 3.0 feet (in./ft)[2]		COAST Model of Total MHHW Elevation for this Scenario Year NAVD 88 (ft.)	Scenario A: WITH NO ADAPTATION ACTION	Scenario B: WITH ELEVATION OF EAST STRAND STREET TO 11 FEET (NAVD 88)	Scenario C: WITH ELEVATION OF BULKHEAD/WITH LEVEE & PATH TO 11 FEET (NAVD 88)	Scenario D: WITH PURCHASES OF ROLLING EASEMENTS, WITH TRANSFER OF TITLE TO CITY AT 2060 OR WHEN MHHW REACHES 6.0 FEET (NAVD 88)
2100	Lo SLR	33	2.75	5.8	46,400,000	4,900,000	241,000	36,900,000
2100	Hi SLR	68	5.67	8.7	44,100,000	4,700,000	446,900	39,576,000

[1]Discount Rate of 3.3% applied.
[2]Does not include purchase of easements at five city-owned properties, and sewage treatment plant remains unprotected.

BENEFIT COST ANALYSIS OF ADAPTATION STRATEGIES – KINGSTON

	Scenario B: WITH ELEVATION OF EAST STRAND STREET TO 11 FEET (NAVD 88)		Scenario C: WITH ELEVATION OF BULKHEAD/WITH PATH TO 11 FEET (NAVD 88)		Scenario D: PURCHASES OF ROLLING EASEMENTS, WITH TRANSFER OF TITLE TO CITY AT 2060 OR WHEN MHHW REACHES 6.0 FEET (NAVD 88)	
	Low SLR	High SLR	Low SLR	High SLR	Low SLR	High SLR
Cumulative Damage to East Strand Study Area With No Action[1]	46,400,000	44,100,000	46,400,000	44,100,000	46,400,000	44,100,000
Cumulative Damage with Adaptation Strategy in Place[1]	4,900,000	4,700,000	241,000	466,900	36,900,000	39,576,000
Avoided Damage (Row 1 – Row 2) or BENEFIT	41,500,000	39,400,000	46,159,000	43,633,100	9,500,000	4,524,000
Estimated COST of Adaptation Strategy	9,800,000		6,200,000		[2]2,540,000	
BENEFIT/COST Ratio (The higher the number above 1, the more favorable the ratio.)	4.2	4.0	7.4	7.0	3.7	1.8

[1]Discount Rate of 3.3% applied.
[2]Does not include purchase of easements at five city-owned properties, and sewage treatment plant remains unprotected.

Scenario B:

WITH ELEVATION OF EAST & WEST STRAND STREETS

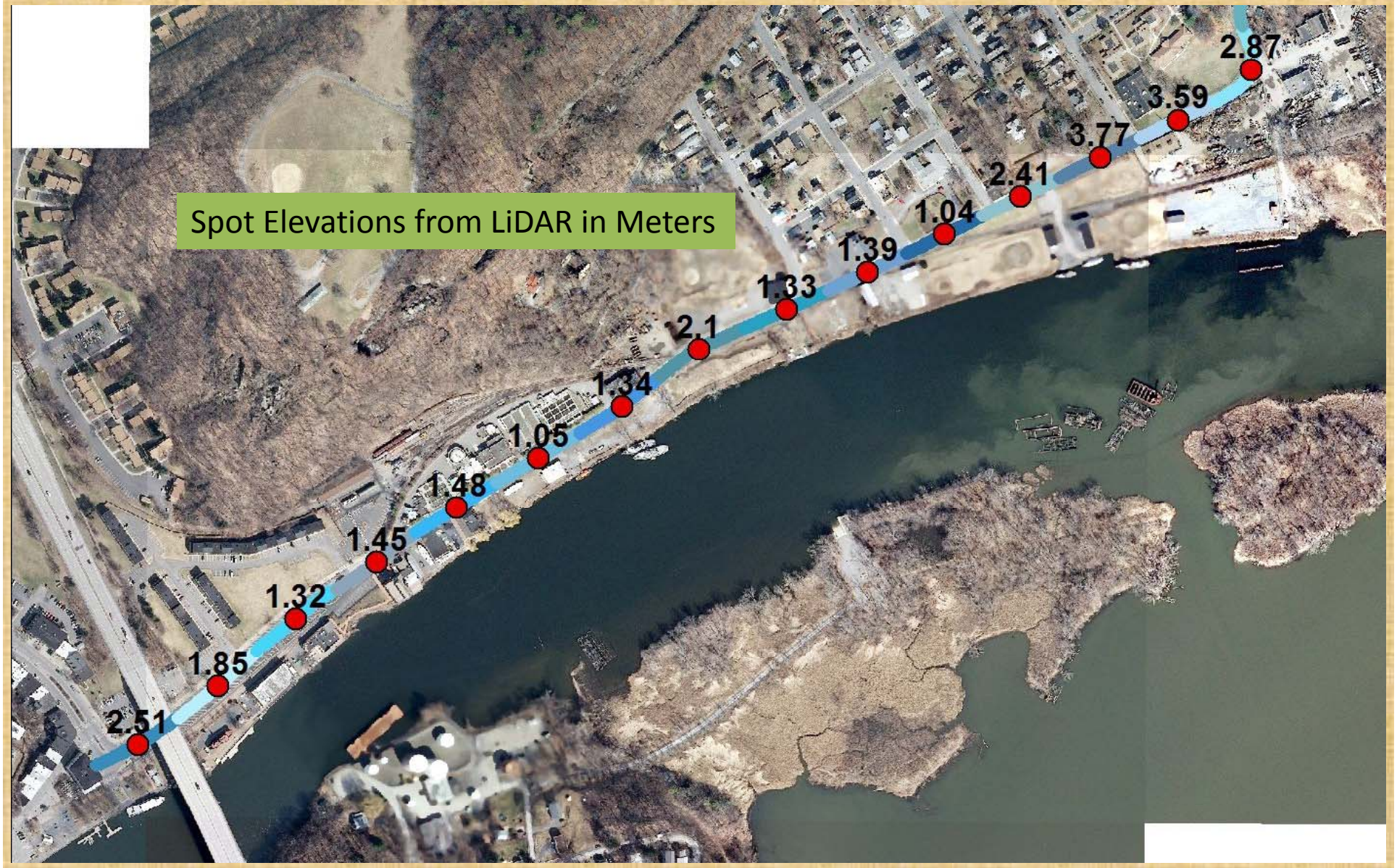
TO 11 FEET (NAVD 88)

- Raise road surface to an elevation of 11 feet.
- Current average elevation is 6.5 feet (4.5 foot difference).
- Project Length: 5,000 feet
- Price per foot estimated: $1,786
- Subtotal – $8.9 million.
- Additional Costs for Ramps, Sidewalk Adjustments – $0.4 million
- Additional Costs for Storm Drainage in Ponckhockie section – $0.5 million
- **Total Estimate: $9.8 million**
- **B/C Ratio = 4.2 or 4.0 (High vs. Low SLR)**

East Strand Street – Currrent Elevations Derived from LiDAR Measurements

Measures of the Height of the Existing Road Surface were taken every 100 m from West to East, and labeled as Stations 1 through 15.

Station	Elevation (Meters)	Elevation (Feet)	MHHW (feet)	Height above MHHW (feet)
1	2.51	8.23	3	5.23
2	1.85	6.07	3	3.07
3	1.32	4.33	3	1.33
4	1.45	4.76	3	1.76
5	1.48	4.85	3	1.85
6	1.05	3.44	3	0.44
7	1.34	4.40	3	1.40
8	2.10	6.89	3	3.89
9	1.33	4.36	3	1.36
10	1.39	4.56	3	1.56
11	1.04	3.41	3	0.41
12	2.41	7.90	3	4.90
13	3.77	12.37	3	9.37
14	3.59	11.78	3	8.78
15	2.87	9.41	3	6.41
Mean	**1.97**	**6.45**	**3.00**	**3.45**
Median	1.48	4.85	3.00	1.85


Spot Elevations from LiDAR in Meters
2.87
3.59
3.77
2.41
1.04
1.39
1.33
2.1
1.34
1.05
1.48
1.45
1.32
1.85
2.51

Scenario C:

ELEVATION OF BULKHEAD/WITH PATH

TO 11 FEET (NAVD 88)

- Raise bulkhead height to an elevation of 11 feet. For majority of length, fill behind bulkhead. For areas close to buildings, build wall behind and cantilever pathway over water.
- Current average elevation is 6.0 feet (5.0 foot difference).
- Project Length: 5,050 feet
- Price per foot estimated: $338 for areas backed by fill
- Subtotal – $1.7 million.
- Additional Costs for One-Time Replacement and Maintenance during the study period (discounting applied) – $1.5 million
- Additional Costs for Easements, Property Acquisition, Cantilevered or Walled Sections – $2.0 million
- Enhancements to Bulkhead to create softer, more resilient shoreline - $1.0 million
- **Total Estimate: $6.2 million, B/C Ratio = 7.4 or 7.0 (Hi vs. Low SLR)**

Scenario D:

PURCHASES OF ROLLING EASEMENTS, WITH TRANSFER OF TITLE TO CITY AT 2060 OR WHEN MHHW REACHES 6.0 FEET (NAVD 88)

- Purchase Easements from all property owners whose land is at less than 11 feet elevation.
- City does not elevate road or bulkhead or make any capital expenditures to mitigate damages over time.
- Owners receive a cash payment now, and can stay on their property until 2060 or when MHHW reaches 6 feet (3 feet higher than today). Title transfers to easement holder at that time.
- Cash payment can be used for flood mitigation for buildings or for any purpose, such as relocation, but owner cannot build a higher bulkhead or otherwise armor the shoreline to prevent inundation or erosion.
- Sewage Treatment Plant remains unprotected.
- **Total Estimate: $2.54 million**
- **B/C Ratio = 3.7 or 1.8 (Hi vs. Low SLR)**

Key Points from the Benefit Cost Analysis

- The Coast Tool and approach are designed to help communities evaluate the merits of various options, and to show which ideas might merit further study.
- Elevation of the Bulkhead along the Strand area appears to have the best Benefit/Cost Ratio of the three scenarios explored.
- More rigorous evaluation of potential costs conducted by an engineering firm will be needed before any actions are taken.
- Experience of Catalysis is that the most cost-effective option is not always the one chosen.

For Questions or Comments, please contact:

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